

National Exams December 2019

18-Env-A3, Geotechnical and Hydrogeological Engineering

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an OPEN BOOK EXAM.
Any non-communicating calculator is permitted.
3. FIVE (5) questions constitute a complete exam paper.
The first five questions as they appear in the answer book will be marked.
4. Each question is of equal value.
5. Most questions require an answer in essay format. Clarity and organization of the answer are important.

Question 1 (20 marks):

The moist weight of $5.66 \times 10^{-3} \text{m}^3$ of a soil is $102 \times 10^{-3} \text{kN}$. The moisture content and the specific gravity of the soil solids are determined in the laboratory to be 11% and 2.7, respectively. Calculate the following properties of the soil in its natural conditions:

- a) (4 marks) void ratio,
- b) (4 marks) porosity,
- c) (4 marks) degree of saturation,
- d) (4 marks) moisture content, and
- e) (4 marks) buoyant unit weight.

Question 2 (20 marks):

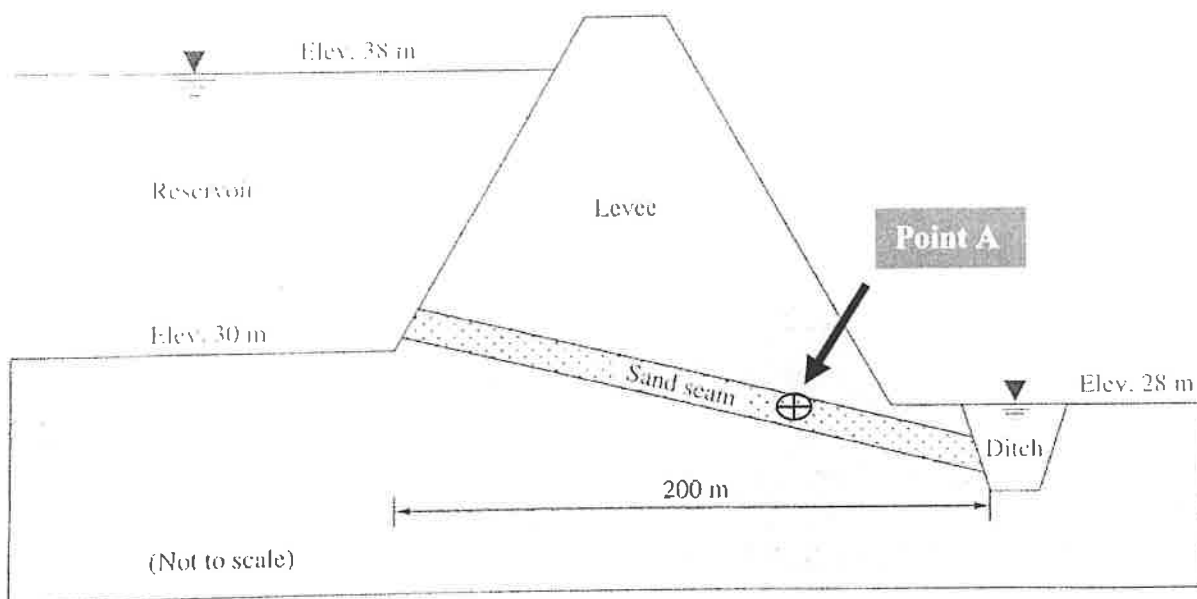
An undisturbed block sample of a soil weighs 900 N and has dimensions of 0.6 m × 0.5 m × 0.4 m. Its moisture content is 20% and assuming the specific gravity of solids is 2.65, compute:

- a) (5 marks) void ratio,
- b) (5 marks) porosity,
- c) (5 marks) moisture content, and
- d) (5 marks) dry unit weight.

Question 3 (20 marks):

Figure below shows a 500 m long levee made of compacted clay that impounds water in a reservoir as shown in the figure below. There is a 1 m thick (into the page) sand seam continuing along the entire length of the levee at 10-degree inclination to the horizontal, which connects the reservoir and the ditch. The hydraulic conductivity of the sand is 2.6×10^{-3} cm/s.

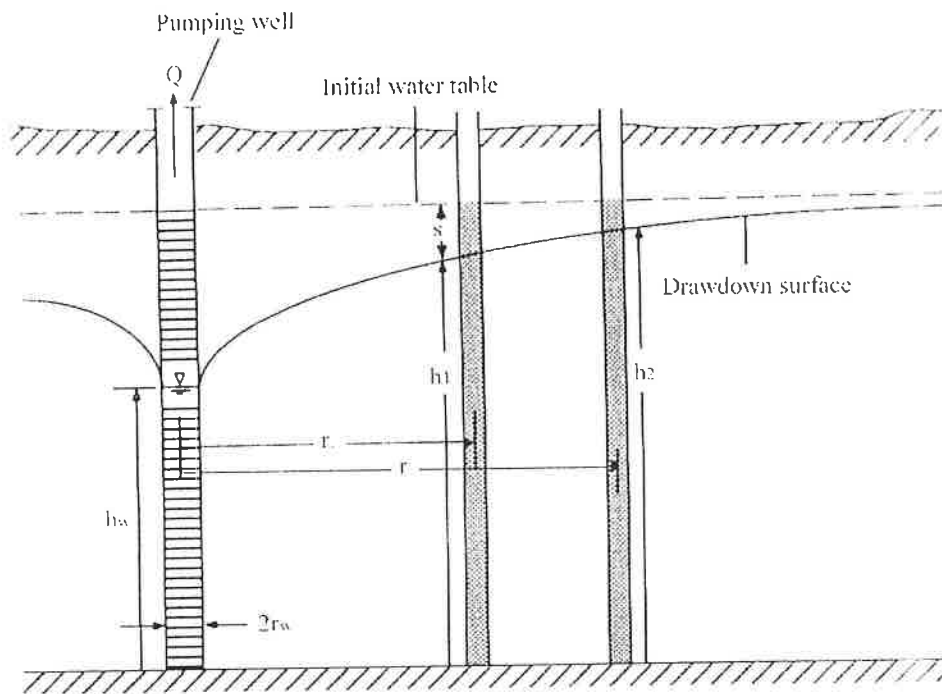
- a) (10 mark) Determine the volume of water that flows into the ditch every day.
- b) (10 mark) Calculate piezometric head at Point A shown below (m)



Question 4 (20 marks):

A municipal water supply well is shown in the figure below. Assuming $h_w = 5$ m, hydraulic conductivity of aquifer $k = 3$ m/d, $r_w = 0.05$ m. Take $r_1 = 30$ m and $r_2 = 50$ m. Consider the following questions:

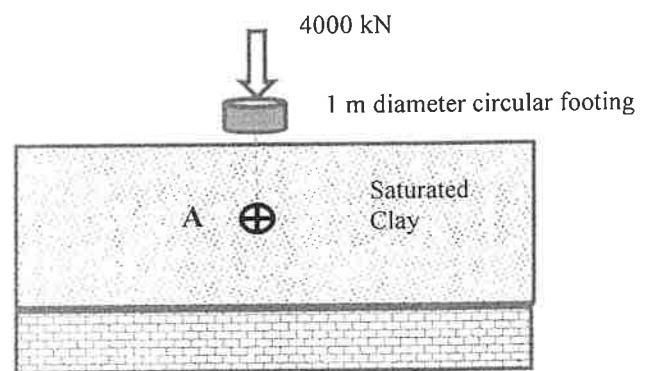
- a) (8 marks) Determine the maximum pumping rate at the well, if the water head in well 2 cannot be lower than 15 m.
- b) (8 marks) Calculate the rise in the well water level h_w if the steady state discharge Q in part a) is dropped by half.
- c) (4 mark) Determine the radius of the circular Wellhead Protection Area (WHPA) for this municipal water supply well based on the 2 year time of travel capture zone.



Question 5 (20 marks):

A 4-m thick normally-consolidated, saturated clay is resting on impermeable rock. A 1-m in diameter circular footing is placed on the ground surface with 4000 kN load. For the clay soil, specific gravity of solids is 2.51, initial void ratio is 3.9, the compression index is $C_c = 0.45$ and recompression index is $C_r = 0.15$.

- a) (8 marks) Compute initial and final effective vertical stresses at midpoint of the clay layer straight below the centre of the square footing (i.e., Point “A”) before and after the placement of the load;
- b) (8 marks) Compute the ultimate primary consolidation of the clay layer straight below the centre of the footing; and
- c) (4 marks) Calculate the change in the void ratio of the clay below the centre of the square footing due to the primary consolidation.



Question 6 (20 marks):

A steep slope is to be cut in an $H = 10$ m height soil with the unit weight of $\gamma = 18$ kN/m³, angle of internal friction of $\phi = 20^\circ$, and cohesive strength of $C = 30$ kN/m².

- (8 marks)** Determine the factor of safety against slope failure if the slope is to be cut at an angle of $\beta = 35^\circ$;
- (8 marks)** Determine what is the maximum angle of the slope β that can be cut to ensure a minimum factor of safety of 1.5 against slope failure; and
- (4 mark)** What other engineering solutions can you suggest to guarantee a safe (factor of safety greater than 3) for a steep slope angle of $\beta = 35^\circ$.

